User requirements towards the use of remote sensing for Natura 2000 habitat monitoring:

a need for formalization

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Outline

1. Implementation of the Habitats Directive: reporting obligations and data needs

2. Different ways to fill in these data needs

3. Formalizing the user requirements for a remote sensing application

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Natura 2000 reporting on habitats

Site level:

- Standard Data Forms and Natura 2000 Database (art. 4(1))
- Appropriate assessments (art. 6(3))
- Compensatory measures (incl. monitoring & reporting on their impact) (art. 6(4))

Member state level:

- Six-yearly national report (art. 17(1)) on conservation status
  area, range, structure & functions, future prospects, trends

EU-level:

- European composite report based on the 6-yearly national reports (art. 17(2))

Reporting on Natura 2000 habitat conservation: what data are needed?

Required data	Standard Data Forms	Appropriate assessments & compensatory measures	Site management	Art. 17 (MS reports & EU-composite report)
Habitat types present	√	√	√	√
Area	√	√	√	√
Habitat patch location	X	√	√	± (area and range)
Quality: overall	√	√	√	√
Quality: per location	X	√	√	X
Trends	X	√	√	± (area and range)
Future prospects	√	√	±	√

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Spatially explicit

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Data collection: different approaches

- Habitat mapping
  - Traditional vegetation mapping in the field
  - Remote sensing
- Habitat quality information
  - Traditional mapping
  - Stratified point sampling
  - Remote sensing

Data collection methods for CS assessment: strengths and weaknesses

	Traditional vege-tation mapping	Stratified point sampling	Remote sensing
Data types	Discrete classes	Quantitative & discrete	Quantitative & discrete (but not individual species)
Spatially explicit	Yes (full coverage)	No (but representative predictions over a predefined region)	Yes (full coverage)
Accuracy assessment	Unformalized	Formalized (statistical analysis)	Formalized
Repeatability	Low to high	High	High
Operational	Yes	Yes	Semi-operational (methods in development)
Time & labour demands	High	Lower (but depending on required accuracy)	Low (‘snapshot’)
Operational cost	High	Lower (but depending on required accuracy)	Potentially lower (but depending on image cost)
Other	Repeatability depends on adoption of stringent rules	Statistical ‘population’ needs to be known (habitat mapping)	Fieldwork remains necessary (calibration, validation)

Data collection for CS: which method for what?

Data types	Traditional vegetation mapping	Stratified point sampling	Remote sensing
Habitat distribution	+	± (difficult for rare types)	+
Habitat area (m²)	+	±	+
Habitat quality	+	+	+
Patch size	+	±	+
Patch connectivity	+	-	+
Species distribution	+	± (difficult for rare spp.)	-
Species richness	+	+	-
Abiotic conditions	± (through indicator values)	± (indicator values, or if directly: at high cost)	± (some, e.g. soil moisture)

Potential of remote sensing methods

- Remote sensing can bring added value to Natura 2000 habitat monitoring:
  - new types of data (spatially continuous) that can be useful for habitat quality assessment
  - higher update frequency
  - possibility for backdating (if images archived)
  - increased standardization and repeatability
  - introduce accuracy assessment in the mapping process
  - enhance cost-effectiveness (lower cost or better quality)

- Considerable effort put into bringing RS into use

- Challenge remains to make it fully operational…

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User requirements for remote sensing applications

- Prevalent needs in habitat mapping are about:
  - geographic extent and area of habitats
  - habitat quality/condition
  - detection of changes

- Common phrasing: “Users need a map of the distribution of x, y, z (habitat types, quality indicators,…) in region A, updated every n years.”

- Providers need more input from end-users.

- Derive clear requirements in terms of characteristics that can be linked directly to remote sensing:
  A. Thematic resolution
  B. Thematic accuracy
  C. Spatial resolution
  D. Temporal resolution
  E. Evaluation framework

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A. Thematic resolution

- Imagine a heathland area in Flanders, where the following habitats are to be mapped:
  - 2310 Dry sand heaths with *Calluna* and *Genista*
  - 2330 Inland dunes with open *Corynephorus* and *Agrostis* grasslands
  - 3110 Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*)
  - 3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
  - 3160 Natural dystrophic lakes and ponds
  - 4010 Northern Atlantic wet heaths with *Erica tetralix*
  - 4030 European dry heaths
  - 5130 *Juniperus communis* formations on heaths or calcareous grasslands
  - 6230 * Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)
  - 6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
  - 7140 Transition mires and quaking bogs
  - 7150 Depressions on peat substrates of the *Rhynchosporion*
  - 9120 Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion roboripetraeae or Ilici-Fagenion*)
  - 9190 Old acidophilous oak woods with *Quercus robur* on sandy plains
  - 91D0 * Bog woodland
  - 91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)
- Could work in the field, but probably not for RS
- Redefine classes in terms of features suitable for RS
- Ex.: heathland classification scheme for Habistat, based on
  - Life form cover and dominant species (cf. BIOHAB: *Bunce et al., 2008*)
  - framework for the assessment of local conservation status of habitat patches (*Heutz & Paelinckx, 2005; T'jollyn et al., 2008*)

Ex.: Matrix for the local conservation status assessment of European dry heaths (4030) in Flanders

4030	indicator	good local conservation status		bad local CS	remarks and explanations
		A – good quality	B - moderate quality	C – low quality	
Habitat structure	coverage of dwarf shrub	≥ 50%		< 50%	dwarf shrubs include: *Calluna vulgaris*, *Erica cinerea*
	age structure of *Calluna vulgaris*	all phases present	2 to 3 phases present	only 1 phase present	phases include: pioneering -, developing -, climax - and degenerating phase
Vegetation	presence of key species	*Calluna* + ≥ 2 other key species	*Calluna* + 1 other key species	only *Calluna* present	key species: *Calluna vulgaris*, *Cuscuta epithymum*, *Diphasiastrum tristachyum*, *Erica cinerea*, *Genista anglica*, *Genista pilosa*, *Lycopodium clavatum*, *Vaccinium vitis-idaea*
Disturbances	encroachment by nitrophil-ous species	< 30%	30% - 50%	> 50%	nitrophilous species: *Molinia caerulea*, *Deschampsia flexuosa*, *Agrostis* spp., *Pteridium aquilinum*, *Rubus* spp.
	tree/shrub encroachment	≤ occasio-nally	< 30%	≥ 30%	

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Disturbances	encroachment by nitrophil-ous species	< 30%	30% -	> 50%	nitrophilous species: *Molinia* …*a flexuosa*, …*m aquilinum*,
	tree/shrub encroachment	≤ occasio-nally	< 30%	≥ 30%	

Hdcy	Calluna-stand of predominantly young age
Hdca	Calluna-stand of predominantly adult age
Hdco	Calluna-stand of predominantly old age
Hdcm	Calluna-stand of mixed age classes

Hgm	Grass-encroached heathland
Hst	Shrub/tree-encroached heathland

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Classification scheme heathland (part)

Level1		Level2		Level3		Level4	
H	Heath-land	Hd	Dry heath-land	Hdc	Calluna-dominated heathland	Hdcy	Calluna-stand of predominantly young age
						Hdca	Calluna-stand of predominantly adult age
						Hdco	Calluna-stand of predominantly old age
						Hdcm	Calluna-stand of mixed age classes
		H w	Wet heath-land	Hwe	Erica-dominated heathland	Hwe-	Erica-dominated heathland
		Hg	Grass-encroached heathland	Hg m	Molinia-dominated heathland	Hgmd	Molinia-stand on dry soil
						Hgmw	Molinia-stand on moist soil
				Hgd	Deschampsia flexuosa-dominated heathland	Hgd-	Deschampsia flexuosa-dominated heathland
		Hs	Shrub/Tree-encroached heathland	Hst	Tree-encroached heathland	Hst-	Tree-encroached heathland
				Hsr	Rubus-encroached heathland	Hsr-	Rubus-encroached heathland

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		Hw	Wet heath-land	Hwe	Erica-dominated heathland	Hwe-	Erica-dominated heathland
		Hg	Grass-encroached heathland	Hgm	Molinia-dominated heathland	Hgmd	Molinia-stand on dry soil
						Hgmm	Molinia-stand on moist soil
				Hgd	Deschampsia flexuosa-dominated heathland	Hgd-	Deschampsia flexuosa-dominated heathland
		Hs	Shrub/Tree-encroached heathland	Hst	Tree-encroached heathland		Tree-encroached heathland
				Hsr	Rubus-encroached heathland		Rubus-encroached heathland

2310/4030

4010

2310 / 4030 / 4010 Quality indicator

2310 / 4030 / 4010 Quality indicator

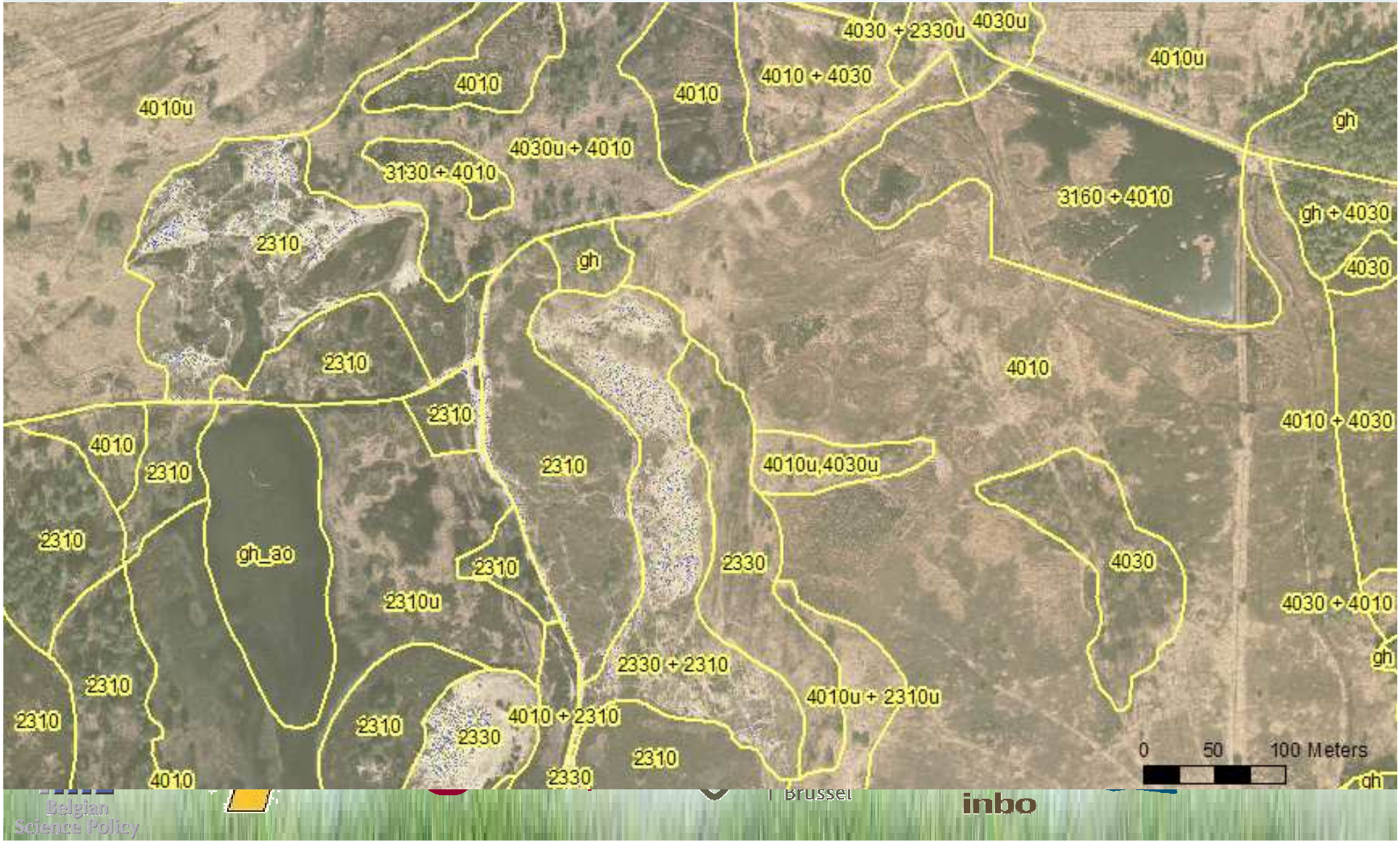
2310 / 4030 Quality indicator

B. Thematic accuracy

- Traditional vegetation maps: accuracy rarely evaluated
- Yet, they are not 100% reliable!

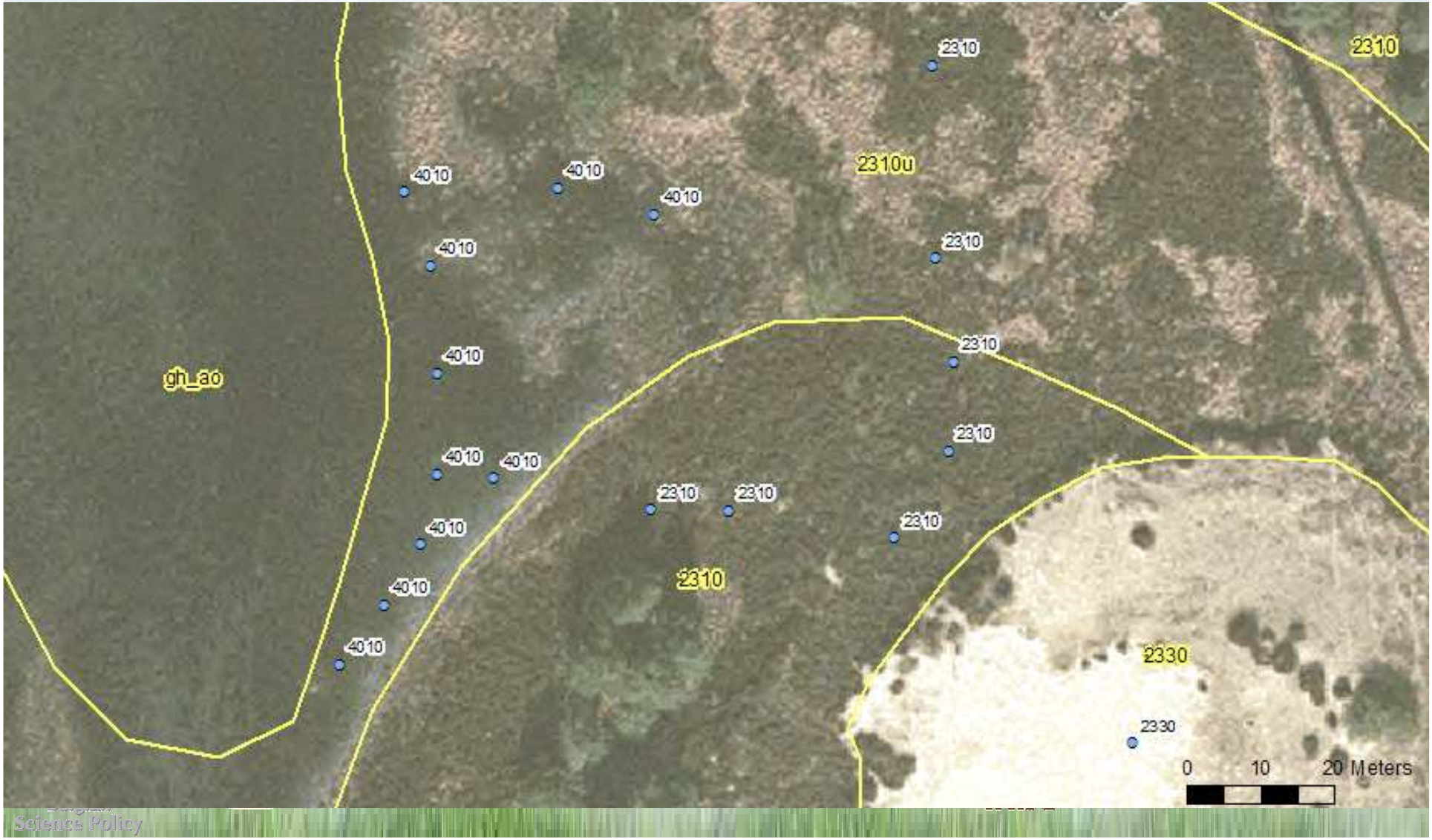
Ex.: The Flemish habitat map v5.1

- derived from field survey (Biological Valuation Map + additional fieldwork)



The Flemish habitat map + recent field reference data

- Ex.: transition moorland pool (gh_ao) – dry heath (2310): belt of wet heath (4010) is not represented on the habitat map



Confusion matrix for the Flemish habitat map

	H2310/ 4030	H4010	H2330	H6230	H6410	H7140	H7150	H9120	H3130	H3160	no ha-bitat	total	'user' acc.
H2310/4030	180	33	52								1	266	68%
H4010	7	171	2			6	5			9	17	217	79%
H2330	1		65	2								68	96%
H6230				9							1	10	90%
H6410												0	0%
H7140												0	0%
H7150	1						1					2	50%
H9120											1	1	0%
H3130									1			1	100%
H3160											2	2	100%
no habitat	7		5	1	1		1			2	264	281	95%
total	196	204	124	12	1	6	7	0	1	11	286	848	overall
'producer' acc.	92%	84%	52%	75%	0%	0%	14%	0%	100%	18%	93%		82%

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B. Thematic accuracy (cont'd)

- Questions to ask:
  - What thematic accuracy is required for a given purpose? (e.g. detecting trends in habitat area within the past six years)
- No easy answer
- Cost-benefits

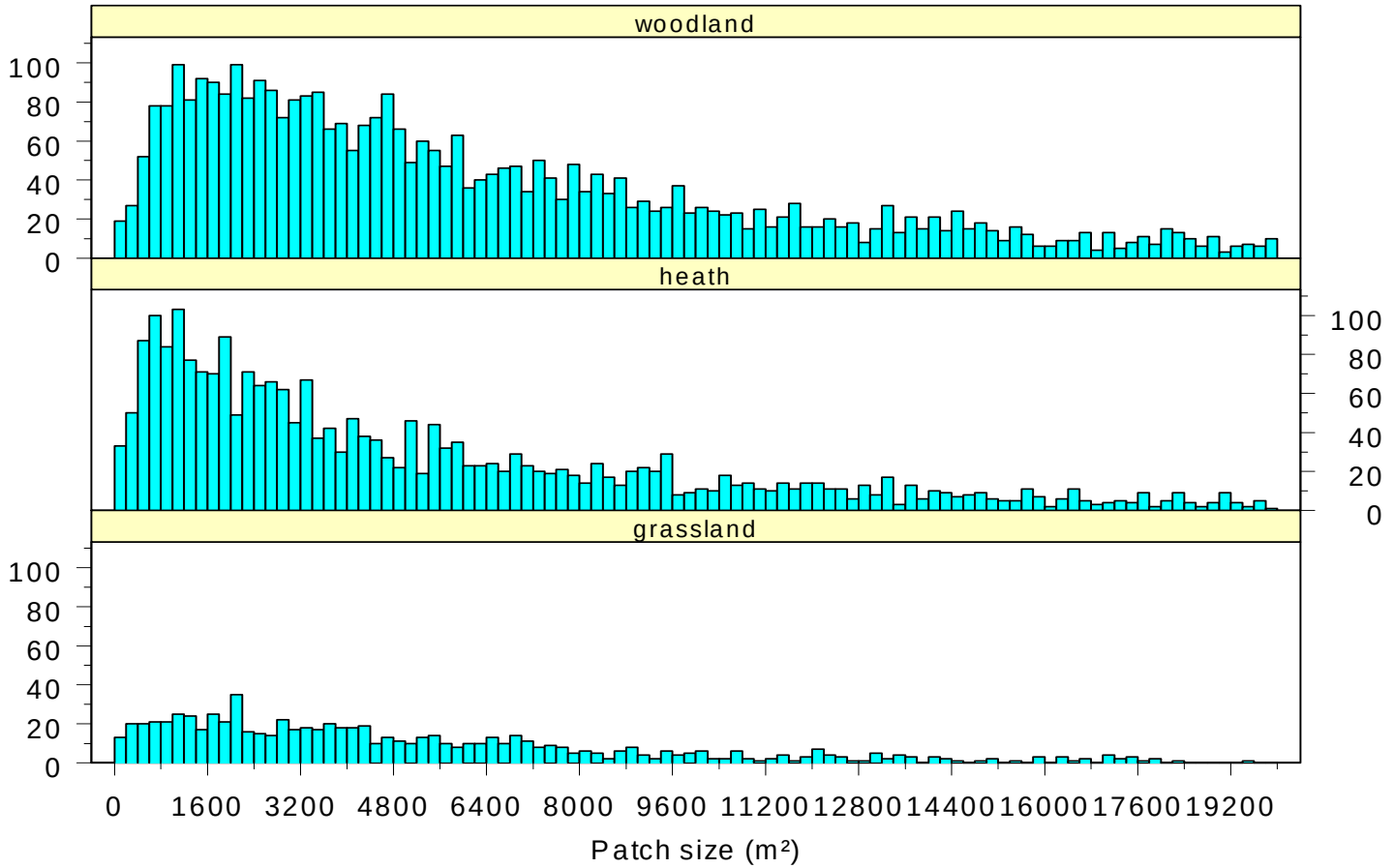
C. spatial resolution and scale

- Questions to ask:
  - What is the intrinsic scale of the habitats or other classes to be mapped? (patterns, ‘structures’)
  - What is the intrinsic scale of processes to be monitored? (‘functions’)

- Ex.: Analysis of patch size distribution for habitat types in the Campine ecoregion
  - based on the Flemish habitat map v5.1
  - 7722 polygons attributed to one and only one habitat type (pure polygons)

Size distribution of habitat patches in Flemish Campine ecoregion, per broad habitat class

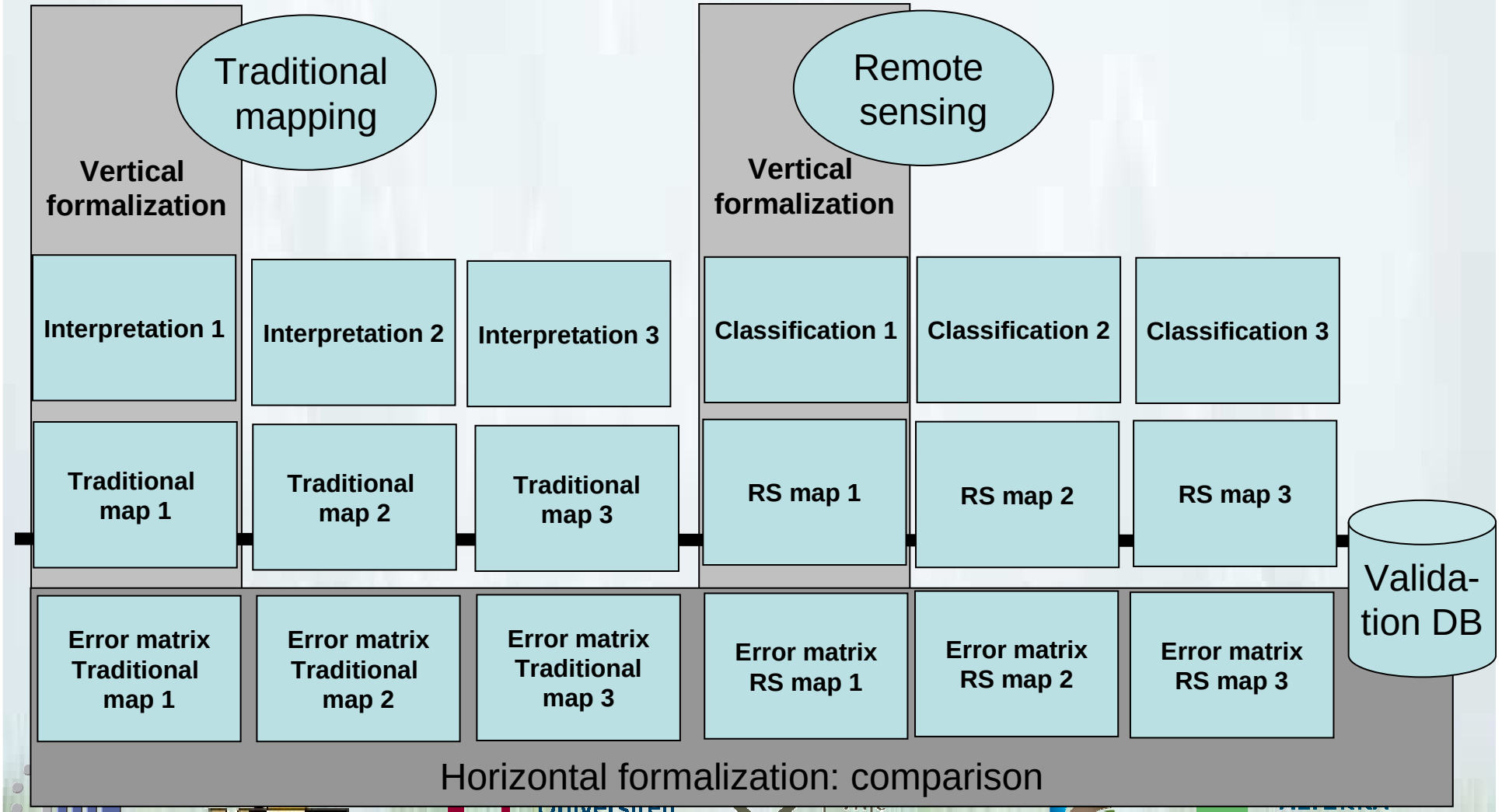
- Overall size distribution peaks at about 1000 m²
- √1000 = 31.6 → 30x30 m pixel resolution OK for habitat mapping?



E. Evaluation framework

- Make cost-benefit analysis of various methods more objective
- Use same approach to evaluate traditional and RS methods
  - Validation (error matrix) on basis of independent validation data for each method
- When comparing methods, take into account:
  - Horizontal formalization: assess various approaches using validation database and compare performance
    (e.g. different observers, for RS: different classification algorithms)
  - Vertical formalization: standardization (automation) of procedures for map derivation
    (e.g. between-observer variability, applicability of RS-methods in new study areas)

Framework for quality assessment & comparison of data collection methods



Summary

- Remote sensing: high potential for habitat monitoring, but cost/benefit is critical for its use
- Lack of operational applications, at least partly because of misunderstandings between users and providers
- Issues of thematic resolution/accuracy, scale, temporal requirements,… have to be stated more clearly for RS to reach its full potential.
- Input from users required
- RS is not the only information available:
  - Fieldwork will always remain necessary
  - Combining RS with ancillary data will further improve its usefulness